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RESPONSE OF PLANTED SHORTLEAF PINE TO OVERHEAD RELEASE

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INTRODUCTION

The present yield of the Missouri Ozark forests is only about one-tenth of their potential productive capacity. Although the forest resource has been severely depleted, it can be restored by the application of proper forest management practices. Adequate protection against burning, overgrazing, overcutting and highgrading, the practices largely responsible for the current low productivity of the forests, is essential to the success of a restorative program. Given this protection, a logical means of increasing the yield of the low-grade forests occupying an estimated seven million acres of land in the Missouri Ozarks is through practices designed to increase the stocking and growth rate of shortleaf pine in the stands.

The range of shortleaf pine, that is, the area on which pine is now growing, includes about four and one-half million acres. It is limited largely to Clarksville stony loam soils in the rough, deeply dissected country in the central Ozark region in watersheds of rivers flowing to the south. Except for a few small remnants of the old-growth stands, the majority of the pine trees are in the reproduction-, sapling-, and small pole-size classes. The close correlation with topographic and other site factors that was evident in many of the old-growth stands has been so altered by past practices that the present distribution of most of the pine is somewhat erratic.

Approximately one million acres of forest, centering in Reynolds, Shannon and Carter Counties, Missouri, are now satisfactorily stocked with pine and need only a stimulation of growth to bring the stands much nearer to their full productive capacity. Another one million acres have enough pine seed trees or potential seed trees to eventually provide for satisfactory natural restocking under good management. This will involve creating conditions more favorable for the germination of seed and the survival and growth of resulting trees. The remaining two and one-half million acres within the present range of pine and an additional estimated two and one-half million acres have too few pine seed trees to provide for satisfactory natural regeneration in a reasonable

time. Here, artificial introduction of pine will be needed to speed up restoration of productivity. It is this approximately five million acres of forests to which the contents of this paper are particularly applicable.

This five-million-acre area supports a highly variable forest cover which, in general, is low in value. The majority of the stands consists of second-growth sapling- and pole-sized trees. A high percentage of the overstory trees is noncommercial blackjack oak and inferior scarlet and post oaks that should be handled on a short rotation. Many are highly defective as a result of the activities of decay organisms that have entered through numerous fire scars and branch stubs. Trees that are now of merchantable size are, for the most part, remnants of the old stands, have a high percentage of cull, and, except for a relatively few trees of white oak and shortleaf pine, should be harvested as soon as feasible. The reproduction is made up largely of sprouts of noncommercial and inferior species which have developed since the last time the area was burned. The generally low quality of the reproduction, saplings, and poles, is largely attributable, either directly or indirectly, to repeated burning, the control of which is essential to the success of any restorative program.

Both the amount of pine to be introduced and the time of its introduction into these stands will vary with stand composition and condition and must be correlated with wise use of existing timber and available manpower. Approximately one-half of the five million acres already has acceptable overall stocking of reproduction of the commercial hardwood species. Here, the primary objective should be to establish groups of pine trees sufficiently well distributed over the area to serve as sources of seed for later and more complete conversion to oak - pine stands. On the other areas where the reproduction of commercial species is not considered adequate, the primary objective should be to secure a full stocking of trees of good species immediately. This will increase the yield during the first rotation and at the same time provide adequate sources of seed for future natural regeneration.

Planting pine in these low-grade stands has been an important part of the forest management work on the national forests of Missouri and will be again with the passing of war-time conditions. Techniques of nursery stock production,[1/]

1/ Auten, John T. Response of shortleaf and pitch pines to soil amendments and fertilizers in newly established nurseries in the Central States. Journal of Agricultural Research, Vol. 70, No. 12, pp. 405 - 426, 1945.

grading nursery stock[2] and planting[3] have been sufficiently well developed to obtain satisfactory survival. However, growth rate of the planted pine, particularly in the dense stands, was so low that it soon became evident that a reduction in competition with the overstory was essential to the success of the pine planted in these low-grade stands.

EXPERIMENTAL WORK

In the springs of 1938 and 1939, the Central States Forest Experiment Station in cooperation with the Mark Twain and Clark National Forests initiated a series of studies to test the effects of removal of overstory trees on survival and growth rate of planted pine. The studies were conducted in low-grade second-growth oak - hickory stands just inside the present range of pine in Howell and Reynolds Counties, Missouri (Fig. 1, A). The stocking of overstory trees 1-inch d.b.h. and larger averaged about 390 per acre; 55 percent were blackjack oak. The trees averaged 40 years in age, 5.7 inches d.b.h., and 33 feet in height. Basal area averaged about 81 square feet per acre and the canopy was 75 to 85 percent closed. The reproduction was 3 to 5 years in age, 1 to 3 feet in height and had a stocking of 1,000 to 5,000 trees per acre. It was mostly of stool sprout origin and had a high percentage of blackjack, post, scarlet and black oaks.[4] The litter was only from 0 to 3 inches deep, because the areas had been burned over within the preceding 3 to 5 years. The soil is Clarksville stony loam and has a gently rolling topography.

The field work consisted of three separate studies involving 78 plots, each 0.1 to 0.2 acres in area exclusive of a 33-foot isolation strip. One study was designed to test four methods of release, including a check, at three seasons of the year; another to test three methods of release of three ages of planted pine at time of release; and another to test three methods at four intensities of release.

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[2] Chapman, A. G. Classes of shortleaf pine nursery stock for planting in the Missouri Ozarks. Journal of Forestry, Vol. 42, No. 11, Nov., 1944.

[3] Planting Section, Timber Management Handbook. U. S. Forest Service, Region 9, Milwaukee, Wis.

[4] Liming, Franklin G. Reproduction in oak - hickory stands of the Missouri Ozarks. Journal of Forestry, Vol. 42, No. 3, March, 1944.

A

B

C

Figure 1. Successive photos of an area typical of those used in these studies. A. At the beginning of the studies — after the overstory trees were girdled and just prior to planting. B. Three years after planting and release. Pine is well established. Tops of overstory trees have started to fall. C. Six years after planting and release. Some of pine trees are 12-15 feet tall. Most of tops are down and fairly well decomposed.

The four methods of release were: (1) Shallow or peel girdle — girdle extending less than 0.1 inch into the sapwood and bringing about a gradual release during the next 2 years; (2) deep or notch girdle — girdle extending 0.1 to 0.5 inch into the sapwood and bringing about release during the next year; (3) cut — cutting with saw or axe and bringing about an immediate release; and (4) check — no change in the overstory.

The five seasons and ages of pine at the time of release were: (1) March — in the dormant season just prior to planting; (2) May — during the early fast-growing season about 2½ months after planting; (3) August — during the late growing season about 5 months after planting; (4) March — 1 year after planting; and (5) March — 2 years after planting.

The four intensities of release were: (1) 0 percent or check — overstory undisturbed, basal area about 81 square feet per acre; (2) 33 percent — basal area of residual trees reduced to 54 square feet per acre in better trees well distributed over the plots; (3) 67 percent — basal area reduced to 27 square feet per acre; and (4) 100 percent — basal area reduced to 0.

All planting was done by regular Forest Service planting crews, using 1 - 0 stock from the Forest Service Nursery at Licking, Missouri. The planting stock averaged 5 to 8 inches tall, which according to studies on stock grades[5/] is a satisfactory height class of stock to use. The trees were planted by the side-hole method and spaced approximately 6 feet apart without giving much consideration to existing trees. The pine trees used for the study on intensity of release were planted in the fall; those for the other two studies were planted in the spring of the year.

Data on survival, height growth, competition by advance hardwood reproduction and new sprouts from cut or girdled trees, and damage by falling tops and branches of cut and girdled trees were taken at the end of each growing season for 3 or 4 years after release. Supplementary data were also taken on soil moisture content and the sprouting of cut and girdled overstory trees.

RESULTS AND DISCUSSION

Effects of Overhead Release on Survival

The survival of the planted pine 3 or 4 years after overhead release averaged about 82 percent and was quite variable

5/ Chapman, A. G. Shortleaf pine stock grades. Manuscript. Central States Forest Exp. Sta., U. S. Forest Service, Columbus, Ohio.

as shown in Table 1, A, B and C. Release by deep girdling and shallow girdling did not materially affect survival of pine regardless of intensity of release or the time at which it was done. Neither did release by cutting affect survival if done during the same dormant season in which the pine was planted or if release was only 67 or 33 percent. Complete release by cutting after the pine trees had been under an overstory for one or two growing seasons resulted in a highly significant but variable increase in mortality (Table 1, B and C). Similar results are likely to occur if the pine is more than 2 years old. Thus complete release by cutting is an unsatisfactory method of releasing pine one or more growing seasons after planting. Most of the mortality occurred during the first year after release and was apparently due to the sudden and drastic change in growing conditions. The mortality of pine released the same year of planting was also highest the first year, largely because of the mortality resulting from planting. Mortality during the second to fourth year after release averaged about 2.5 percent per year and there is no evidence to indicate that it changed very much during the next several years.

Mortality resulting from competition with hardwood reproduction was negligible. At the end of the fourth year the mortality of pine closely surrounded or even overtopped by hardwood reproduction was essentially the same as for those with little or no competition. Just how long this situation will continue is problematical.

The tops of cut and girdled trees did very little damage to the pine trees when they fell but did greatly increase the fire hazard. Less than 1 percent of the pine trees was seriously damaged, including a negligible amount of mortality, by the falling tops and limbs. A few others were bent over but recovered as soon as the branches rotted sufficiently to break and release them. The shallow-girdled trees stood longer and fell in smaller pieces than did the deep-girdled trees because of the higher proportion of the latter that broke at the girdle. During the first 4 years after cutting and the fourth and fifth years after girdling, when most of the tops were down and before they decayed and settled to the ground, the tops created a serious fire control problem. Because of the increased fire hazard, large areas, on which many trees per acre are to be cut or girdled, should be crossed with sufficient fire breaks or untreated strips to facilitate fire control.

From the standpoint of survival there are two important points that should be kept in mind when releasing planted pine. (1) Of the combinations of releases tested, only complete release by cutting 1 or 2 years after planting resulted in a survival significantly different from that on the check

Table 1. — Survival percents of 1-0 shortleaf pine at the end of the first growing season after overhead release and in the fall of 1941

(A) Planted in March 1938 and released 100 percent that same year as indicated

Overhead release	Method of overhead release									
	Cut		Deep girdle		Shallow girdle		Check		All	
	'38	'41	'38	'41	'38	'41	'38	'41	'38	'41
Month of Release	Percent									
March	89.5	87.0	99.0	92.5	68.5	62.5	90.5	86.5	86.9	82.1
May	80.0	80.0	71.0	67.0	83.0	80.5	80.0	70.0	78.5	74.4
August	92.0	86.5	83.5	80.5	93.0	81.0	97.0	93.0	91.4	85.2
All	87.2	84.5	84.5	80.0	81.5	74.7	89.2	83.2	85.6	80.6

(B) Planted March '39, '38, and '37, and released 100 percent March 1939

Field Age of Pine When Released	'39	'41	'39	'41			'39	'41	'39	'41
0 year	91.5	90.0	98.0	98.0	-	-	97.0	93.5	95.5	93.8
1 year	79.0	78.5	98.0	97.5	-	-	97.0	95.0	91.3	90.3
2 years	84.0	83.0	97.5	89.5	-	-	95.0	86.0	92.2	86.2
All	84.8	83.8	97.8	95.0	-	-	96.3	91.5	93.0	90.1

(C) Planted in the fall of 1936 and released as indicated in March 1938

Intensity of Release	'38	'41	'38	'41	'38	'41			'38	'41
100 %	12.4	7.6	95.4	81.7	100.0	76.3	-	-	75.9	55.2
67 %	84.0	71.3	95.0	90.0	98.7	81.4	-	-	92.6	80.9
33 %	100.0	86.9	92.0	83.6	97.9	89.4	-	-	96.6	86.6
0 %	98.7	78.0	90.5	83.1	94.4	74.4	-	-	87.9	78.5
All	73.8	61.0	93.2	84.6	97.8	80.4	-	-	88.2	75.3

plots. This type of release so lowered the survival that it should not be used unless necessary in order to make full use of trees in the overstory. This is not likely to place any serious restrictions on release work, since release by cutting will be limited largely to harvest cuttings which, under existing conditions, seldom results in clear cutting because of the presence of cull trees and trees below merchantable size. (2) Survival of planted pine on the check plots was as good as that on the released plots during the first 4 years and, from more recent observation, appears to be equally good at the end of 8 years. This good survival under hardwood overstory trees is of particular importance in the planting of areas supporting a few trees or small groups of trees that will be harvested in 5 to 10 years. It may be desirable to plant pine under such trees when the rest of the area is planted. Although it will not make good growth, as pointed out later, it will survive and be on the ground when these trees are harvested and thus eliminate the necessity of a second planting job to secure a satisfactory stocking of pine.

Effects of Overhead Release on Growth

The great increase in height growth was the most significant effect of overhead release on planted pine. Of the combinations of three methods, five ages, and four intensities of release tested, all except those involving a 33-percent release resulted in a significant increase in the height growth of the pine over those given no release.

Methods of Release. The extent to which the height growth of planted shortleaf pine was increased by overhead release was essentially the same for release by cutting, deep girdling and shallow girdling. First-year height growth response appeared to be a little better for release by cutting than for girdling. However, at the end of the third and fourth years there was no apparent difference in total height. The early advantages of an immediate release by cutting were offset by later benefits resulting from the shade of the dead tops of girdled trees and a heavier leaf litter following girdling. Because of their similarity, the data on height growth for the three methods are combined in subsequent discussions of the effect of release on height growth.

The method of release can therefore be chosen on the basis of cost, convenience, and utilization of the overstory trees. Merchantable trees should, of course, be removed in harvest cuttings. In most cases deep or notch girdling is the cheapest and therefore the best method of disposing of trees with no present or future commercial value. Shallow girdling resulted in less sprouting and more gradual deterioration of the tops, but, as discussed below, these advantages are relatively unimportant in releasing planted pine and do not justify the added cost of making the shallow girdle.

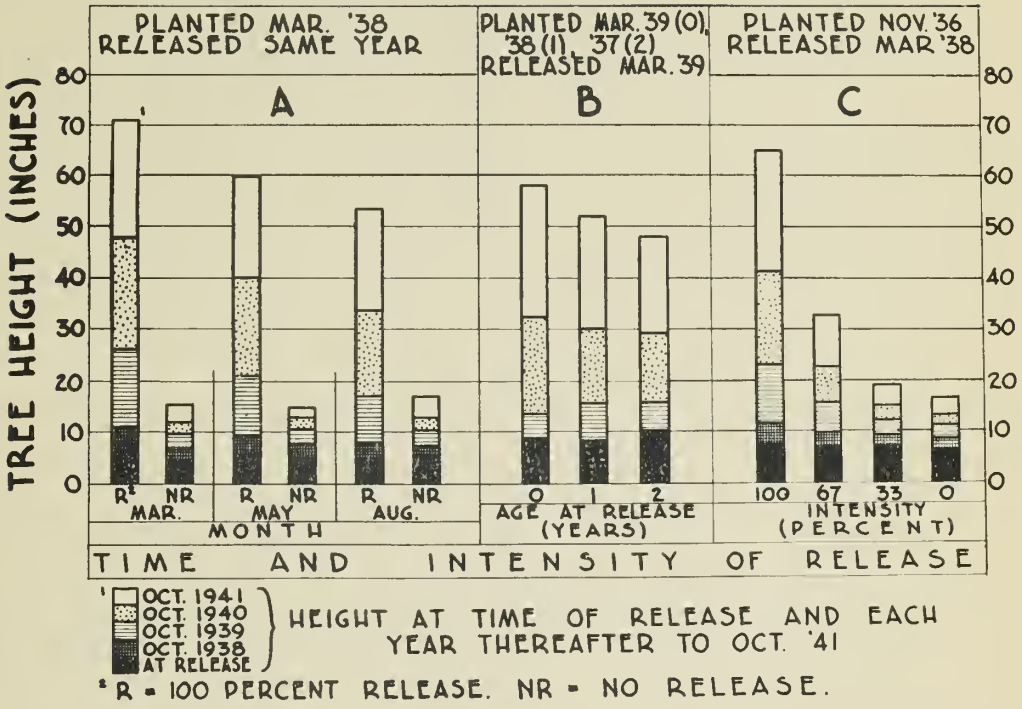

Figure 2. Average yearly increment and total height of 1-0 shortleaf pine trees planted in low-value second-growth oak-hickory stands and released from above as indicated.

Time of Release with Respect to Time of Planting. Delaying complete overhead release of planted pine into and after the first growing season decreased the response of the pine to release. However, all completely released pine made significantly greater height growth than unreleased pine (Fig. 2, A). The growth rate of the unreleased pine was quite constant during the first 4 years, averaging only 2.6 inches per year. At the end of the fourth year the trees averaged 15.7 inches in height. The growth rate of the released pine increased during each of the first 4 years and, although specific measurements were not made after 4 years, further increases have been observed (Fig. 1, B and C and Fig. 2, A, B and C). During the third and fourth years the mean annual height growth was 22.3 inches for the pine released in March at the time of planting. These same pine trees averaged 70.7 inches in height at the end of the fourth growing season. Thus, release in March, at the time of planting, increased the total height 4.7 times, the average 4-year growth rate 6.2 times, and the third- and fourth-year growth rate 8.3 times.

Delaying the release from March into May and August of the same year reduced the average 4-year height from 70.7 to 59.9 and 53.5 inches, respectively. Whereas the height growth of the trees released in March averaged 22.3 inches during the third and fourth growing seasons after release, the growth of those released in May and August averaged only 18.3 inches. Apparently postponing release into the first growing season after planting, thus allowing the trees to start growth under an overstory, reduces the response of pine to release for at least 4 years.

Planting pine 1 or 2 years prior to release had the same general effect on post-release growth as delaying the release into the first growing season after planting. The small amount of growth that occurred during the extra years when the pine trees were under the overstory was more than offset by the reduced post-release growth which resulted from delayed release (Fig. 2, B). Three growing seasons after release, the total height of pine planted at the time of and 1 and 2 years prior to release averaged 58.0, 52.1 and 48.2 inches, respectively. The retarding effect of delaying release extended into the third growing season as evidenced by third-year increments of 25.4, 21.9 and 18.7 inches.

From the standpoint of good growth and survival, pine planted in low-value hardwood stands should be released from above as soon as feasible. Release at the time of planting or during the current dormant season is best but a release during the preceding summer or a few years after planting is much better than no release. Where the overstory contains some merchantable trees, the planting, harvest cutting and

improvement cutting [6] programs for a particular area should be combined into one coordinated action program.

Intensity of Release. Height growth of planted shortleaf pine increased directly with the degree of overhead release. At the end of the fourth growing season after release, the total heights averaged 16.5, 19.1, 32.8, and 64.7 inches, respectively, for trees given 0, 33, 67, and 100 percent release (Fig. 2, C). The total basal area of overstory trees on the plots before release averaged approximately 81 square feet per acre. Reducing this to 54 square feet, a reduction of 27 square feet or 33 percent, resulted in a growth increase over the check of only 2.1 inches, a nonsignificant amount. An additional, equal reduction in basal area, from 54 to 27 square feet, resulted in a significant increase of 13.5 inches. The final 27 square feet reduction, from 27 to 0 square feet, resulted in a still greater increase of 31.6 inches. In general, the average annual growth and the differences among growth rates of pine given different amounts of release increased during each of the first 4 years and are expected to continue to increase during the next few years.

Although complete overhead release resulted in much better growth of pine than partial release, it will be impractical in many stands because of the presence of scattered trees or small groups of trees that should be retained for future harvest. In most cases it will be possible to make at least a 67-percent release, if all trees ready for harvesting are cut and if other trees that have no present or future commercial value are cut or girdled. Also, in most of these low-value stands, it will be necessary to combine a harvest cut and an improvement cut in order to secure sufficiently good growth of the pine to warrant a planting program.

Because of the greater variations among heights of pine within plots given a 67-percent release, the average height figure for pine shown in Figure 2, C, does not give a complete picture of the response to this intensity of release. This amount of release created scattered openings of such size that the pine in the center of many of the larger ones (see section below for data on size of openings) grew as rapidly as completely released pine. The low growth rate of pine near residual overstory trees lowered the average height. For example, the heights of the best 125 trees per acre on areas with 100-percent and 67-percent releases averaged 12 percent and 30 percent greater than the heights of all the pine on the same areas.

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[6] The term "improvement cutting" as used in this paper includes both the cutting and girdling of overstory trees with no present or future commercial value.

On the basis of these findings it is concluded that overhead release of pine planted in these low-grade stands should be as complete as wise use of the overstory trees will permit. Also, planting under second-growth stands should be limited to those stands where the basal area is or can be reduced to about 27 square feet per acre or where numerous openings can be created as discussed below. To do this most efficiently, planting should be closely correlated with harvest cutting and improvement cutting.

Release and Soil Moisture

Soil moisture is an important factor in the growth of pine and in the Missouri Ozarks it may be limiting. The area is much drier than the 35 to 45 inches annual rainfall would indicate. Poor distribution and character of rainfall, excessive run-off and subsurface drainage, low water-holding capacity of the soil, and high evaporation rates are factors contributing to dry conditions.

During the summer of 1940, the third growing season after release, soil moisture determinations were made on random samples from the top 6 inches of soil on the plots used in the study of method and intensity of release. The results are given in Table 2. The moisture content of composite samples of soil that were thoroughly saturated with water and then allowed to drain averaged 24 percent of the air-dry weight of the soil. On May 15 the moisture content of the soil averaged 18.3 percent and was about the same for all methods and intensities of release. By July 2 it had decreased to an average of 15.7 percent for all releases. It remained about the same, 18.6, for complete release and decreased progressively to 13.2 percent for no release. By September 9 it had decreased to 6.4 percent for all releases and ranged from 10.5 for complete release to 4.3 for no release. As with height growth of pine, the greatest differences in soil moisture were between the 67 and 100 percent releases. In general, the moisture content of the soil in July and September was lower for releases made by cutting than for those by girdling.

The lower moisture content of soil in July and September on areas with living overstory trees is believed to be due primarily to the great amount of water lost through root absorption. This more than offsets any beneficial effects of shade, reduced air movements, and greater amount of litter produced by the living trees. The soil moisture differences between methods of release were due largely to the shade provided by the tops of dead trees and the slightly greater amount of litter on areas released by girdling.

Table 2. – Soil moisture, as percent of air-dry soil weight, [1] in top 6 inches of soil on areas released as indicated in March, 1938

Percent release	Dates on which soil samples were taken											
	May 15, 1940				July 2, 1940				Sept. 9, 1940			
	Methods of release				Methods of release				Methods of release			
	Cut	Girdle		All	Cut	Girdle		All	Cut	Girdle		All
		Deep	Shal-low			Deep	Shal-low			Deep	Shal-low	
	Percent											
100	18.1	18.4	19.1	18.5	16.2	19.3	20.4	18.6	7.7	11.7	12.0	10.5
67	17.7	17.7	18.5	18.0	15.1	17.1	15.9	16.0	5.4	5.5	7.2	6.0
33	18.1	18.2	18.2	18.2	15.4	15.7	14.0	15.1	4.2	5.4	5.2	4.9
0	20.2	18.6	16.5	18.4	13.5	11.6	14.5	13.2	4.5	3.9	4.5	4.3
Average	18.5	18.2	18.1	18.3	15.0	15.9	16.2	15.7	5.4	6.6	7.2	6.4

[1] The moisture content of composite samples of this soil after being saturated and allowed to drain averaged 24 percent of air-dry soil weight.

The above data on soil moisture have the same general trends as those on height growth rates of pine reported in the preceding section. These studies did not provide information on the extent to which the growth rate of pine was correlated with specific changes in light intensity and other site factors effected by overhead release. A more comprehensive study will be necessary to ascertain the relative importance of each of the many interrelated site factors in the survival and growth of pine in the Missouri Ozarks.

Distance to Which Overstory Trees Retard Growth

Inasmuch as some overstory trees will be left on most of the areas that are planted to pine, the question immediately arises as to how close pine should be planted to these trees. This depends primarily on the size and stocking of the overstory trees and the length of time they are to remain in the stand. The data in Figure 3 provide the basis for at least a part of the answer. The center vertical line represents the border of an untreated stand on the left and an area with all overstory trees cut or girdled on the right. The curve represents the heights of 5-year-old pine trees at different distances from the trunks of trees in the edge of the stand into the untreated stand and into the adjacent cleared area. The retarding effect of the overstory trees on the growth of pine is again very evident. It extended into the cleared area for a distance of about 40 or 45 feet. This distance was essentially the same on the north, east, south, and west sides of the stands. However, it varied directly, as much as ± 30 percent, with the size and stocking of trees in the edge of the stand.

In order to obtain a satisfactory stocking of pine on many of the areas, it will be necessary to accept something less than full growth of the pine and to plant closer than the 40 to 45 feet to some overstory trees. In most cases it will be satisfactory to plant as close as 10 to 20 feet to an individual tree or small clump of trees; 15 to 25 feet to trees in the edge of a stand; and 15 to 30 feet to trees around the edge of openings in the stand. The actual distance varies directly with the size and stocking of the overstory trees. Pine should not be planted under the crowns of such trees.

Pine can be planted as close as 5 or 6 feet to overstory trees that are to be removed within 5 to 10 years after planting. Although the pine will not make good growth while it is under the overstory trees, it will survive. Then when the trees are cut the pine will be there and it will not be necessary for a planting crew to cover the area again to fill in the openings.

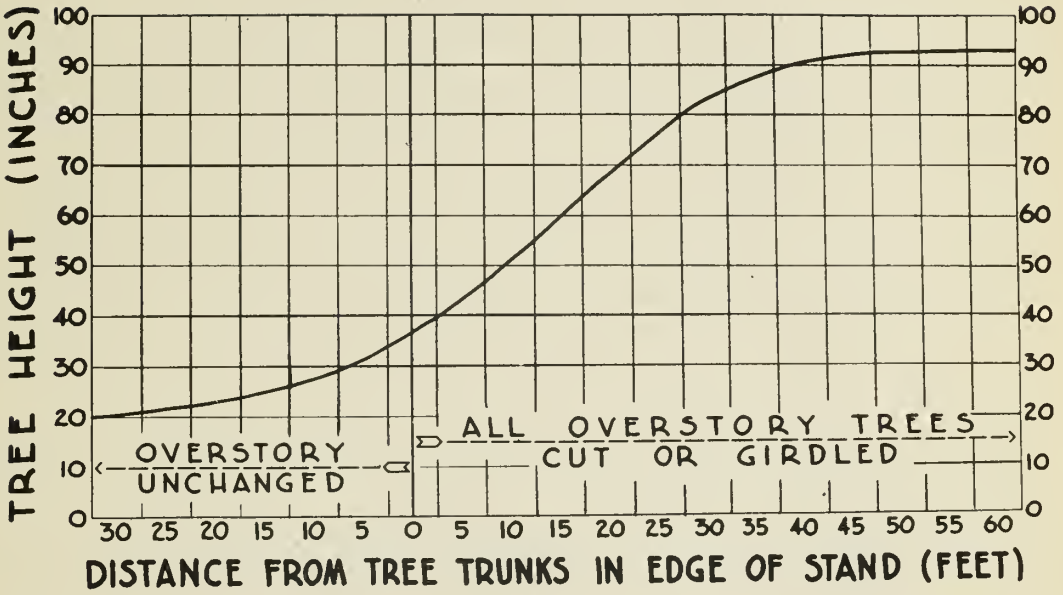


Figure 3. Average height of five-year-old planted shortleaf pine trees at different distances into adjacent treated and untreated low-value second-growth oak - hickory stands.

In general, an area should not be considered a good planting chance unless it is possible to plant at least 200 pine trees per acre under the conditions described above.

Effects of Hardwood Reproduction on Survival and Growth

The advance hardwood reproduction and new sprouts from cut and girdled trees did not seriously interfere with the survival and growth of planted pine. Even though the pine trees were planted on a rather strict 6 x 6-foot spacing, only 20 percent of them were close enough to hardwood reproduction to be overtopped or severely crowded during the first 4 years. In other words about 80 percent of the pine had an equal or better chance of outgrowing the hardwood reproduction. On the basis of more recent observations on the relative growth rates of pine and hardwoods the above figure is conservative. The amount of overtopping was slightly greater for pine released by cutting and deep girdling than for those released by shallow girdling, primarily because of the greater number and larger size of sprout clumps following cutting and deep girdling. It was also slightly greater for pine given delayed release, largely because of the lower growth rate of pine so released.

The advance hardwood reproduction does not make any material response to release during the first 3 years thereafter. The response of pine, particularly if released at the time of planting, is greater and much quicker thus giving the pine a distinct and apparently lasting advantage over the hardwoods. The average growth rate of the new sprouts from cut or girdled overstory trees and from advance hardwood reproduction cut at the time of overhead release [7] is greater than that of pine for the first 2 or 3 years. After the third or fourth year it is equal to or slightly less than that of the pine. As was true of the overstory trees, the presence of hardwood reproduction did not materially affect the survival of the planted pine during the first 4 years. Also, the growth rate of the pine was not noticeably lowered by the hardwood reproduction except where the pine was overtopped by it. In general, unless the pine is overtopped within 4 or 5 years, its growth rate can be expected to equal or surpass that of the hardwood reproduction.

Competition with hardwood reproduction was too low to warrant a second release in the understory and can be further reduced in future plantings by giving more consideration to

7/ Liming, Franklin G., and B. F. Seizert. Relative height growth of planted shortleaf pine and cut-back and uncut hardwood reproduction after release. Journal of Forestry, Vol. 41, No. 3, March, 1943.

the selection of the planting spot. It is therefore recommended that pine not be planted closer to advance hardwood reproduction than 2 feet or a distance equal to the height of the hardwood, or closer than 5 or 6 feet to an overstory tree that is to be cut or girdled in the current overhead release.

Coordinating Forest Planting with Harvest and Improvement Cutting

If full use is to be made of overstory trees and if full benefit to planted pine is to be obtained from reduced competition, planting, harvest cutting and improvement cutting must be done concurrently. Most of the stands in which pine should be planted have an overstory of which less than one-third is ready for harvest, one-third is growing stock, and slightly over one-third is cull. Thus, a harvest cut or an improvement cut alone results in only about a 33-percent release, which does not bring about a significant increase in the height growth of pine. Planting under such conditions is of questionable economic value. However, a combination harvest and improvement cut gives about a 67-percent release which does result in a significant and worthwhile increase in growth. A complete release, although it results in a still better growth, is seldom justifiable because of the waste of immature trees. Release prior to planting gives the sprouts and other hardwood reproduction, shrubs and weeds a start on the pine and results in more serious competition. Delayed release reduces the response and results in the loss of the advantages of a high early growth rate. Although any release that removes more than one-third of the overstory or reduces the basal area below 54 square feet per acre is better than no release, most efficient use of time and money can be made by releasing current plantings and doing as complete a job as practicable on the area covered.

In brief, recommendations for effective coordination of the work are: (1) Where practicable, make harvest cuttings on areas to be planted and conversely plant, if needed, on areas to be covered by harvest cutting. (2) Concentrate improvement cutting on planting areas covered by harvest cutting and make both cuttings as heavy as practicable. (3) Do the different phases of work as nearly concurrently as feasible.

SUMMARY

A logical means of increasing the yield of an estimated seven million acres of low-grade forests in the Missouri Ozarks is through practices designed to increase the stocking and growth rate of shortleaf pine in the stands.

A series of studies was initiated in 1938 to ascertain which of three methods, four intensities, and five times of

removing overstory trees would result in the best survival and growth of pine planted in these low-grade stands.

Pine planted under second-growth oak - hickory stands with an average basal area of 81 square feet per acre survived well the first several years but made very slow growth. Survival at the end of the first and fourth years averaged about 91 and 84 percent, respectively. Average total height was about 15.7 inches at the end of the fourth year. Height growth averaged about 2.6 inches per year.

The survival of the pine, although quite variable, was altered significantly by only one of the combinations of releases tested. Complete release by cutting after the pine had grown under the overstory 1 or 2 years resulted in an unsatisfactorily low survival.

A highly significant increase in height growth rate of planted pine was obtained by all releases greater than 33 percent. There was no significant difference between the growth rates of pine given 33-percent and 0-percent release.

The response in height growth was essentially the same for release by cutting, deep girdling and shallow girdling.

Pine given complete release in March, at the time of planting, averaged 70.7 inches in height at the end of the fourth growing season. This is about 4.7 times that of the unreleased pine. The average growth rate for the 4-year period was increased 6.2 times and that for the third and fourth years was increased about 8.3 times.

The heights of pine trees that were not released until May and August after planting in March averaged 59.9 and 53.5 inches, respectively, at the end of the fourth growing season. These were 10.8 and 17.2 inches less than those released in March at the time of planting. The retarding effect of delaying release was still evident in the growth rate during the fourth year.

At the end of the third growing season after release, the heights of pine trees released in March at (a) the time of planting, (b) 1 year after planting, and (c) 2 years after planting averaged 58.0, 52.1, and 48.2 inches. Differences in height growth rate were still evident during the third year. The growth rate of pine after delayed release was still more than 5 times that of the unreleased pine.

Height growth rate increased progressively with increase in intensity of overhead release. Heights of trees given 0, 33, 67 and 100 percent releases averaged 16.5, 19.1, 32.8 and 64.7 inches, respectively, at the end of the fourth growing

growing season. The fourth-year increment for the same intensities of release averaged 3.3, 3.8, 9.8 and 23.3 inches. Thus, the differences in heights increased each year and apparently will continue.

The increases in growth rate of planted pine resulting from overhead release were closely correlated with increases in soil moisture. The extent to which they were correlated with changes in other site factors was not obtained in these studies.

Overstory trees retarded the growth of planted pine trees within 40 to 45 feet of their trunks. The actual distance varied directly, as much as ± 30 percent, with size and stocking of overstory trees.

The relatively low growth rate of the hardwood reproduction made a second release unnecessary. Only about 20 percent of the pine was overtopped or seriously crowded by the hardwoods. Most of this can be avoided by a better selection of the planting spots.

Most efficient use of time and money for planting and release can be had by releasing current plantings first and doing as complete a job as feasible on the area covered.

RECOMMENDATIONS

Underplanted shortleaf pine should be released from above as completely and as soon as is consistent with wise use of the overstory trees. Current plantings should be given priority over older plantings.

Trees ready for harvest should be cut. Trees with no present or future commercial value should be girdled in whatever way is most convenient and economical.

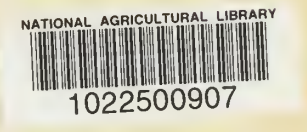
Large areas on which many trees per acre are to be cut or girdled should be crossed with sufficient fire breaks or untreated strips to facilitate fire control.

Pine should not be planted closer to advance hardwood reproduction than 2 feet or a distance equal to the height of the reproduction, or closer than 5 or 6 feet to cut or girdled trees or trees that are to be harvested within 5 to 10 years.

Pine should not be planted under or within 10 to 25 feet of hardwood overstory trees that are to be left in the stand for more than 10 years.

In most cases planting should be limited to stands in which the basal area of the overstory trees is or can be reduced to about 27 square feet per acre or to stands with sufficient openings to plant about 200 trees per acre at least 10 to 25 feet from residual trees. This does not preclude the possibility of planting scattered groups of trees in the better stands to serve as future seed trees.

The harvest cutting, improvement cutting, and planting programs should be so planned that all phases of work in need of being done on a particular area can be done as nearly concurrently as feasible.



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